ORIENT- NM

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Work Package 4 – Interaction with other bodies, initiatives and stakeholders, including infrastructures

Deliverable D4.9: Revised protocol of EJP collaboration with standardisation, data and knowledge management and safety bodies

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List of abbreviations

AFCEN	L'Association française pour les règles de conception, de construction et de surveillance en exploitation des matériels des chaudières électro-nucléaires
ASME	The American Society of Mechanical Engineers
ASTM	The American Society for Testing of Materials International
CEN	Comité Européen de Normalisation
CEP	Co-funded European Partnership
CRP	Coordinated Research Project
CORDEL	Cooperation in reactor design evaluation and licensing
EC	European Commission
ECCC	European Creep Collaborative Committee
EJP	European Joint Programme
EMCC	European Material Characterization Council
EMMC	European Materials Modelling Council
EPERC	European Pressure Equipment Research Council
ESIS	European Structural Integrity Society
ETSON	European Technical Safety Organisation Network
EU	European Union
FR	Fast Reactors
GIF	Generation IV International Forum
GRS	Gesellschaft für Anlagen und Reaktorsicherheit
IAEA	International Atomic Energy Agency
ISO	International Organization for Standards
MS	Member State
OECD/NEA	Organisation for the Economic Cooperation and Development / Nuclear Energy Agency
PWR	Pressurised Water Reactor
R&D	Research and Development
SFR	Sodium Fast Reactor
TSO	Technical Safety Organisation
WNA	World Nuclear Association

Summary

This document describes briefly how the future European partnership on nuclear materials may seek grounds for interaction and collaboration with a number of stakeholders, including organisations, networks and European associations addressing Codes & Standards, regulation and harmonisation of testing and assessment of component and materials. The premise is that there should be a mutual benefit and a future European Co-funded European Partnership on nuclear materials and components. The first stage was the identification of stakeholders and thereafter discussion with some key organisations, including AFCEN, ECCC, EPERC, CORDEL, ETSON and EMMC. This report is a revision of the Deliverable 4.2 “Draft protocol of EJP collaboration with standardisation, data and knowledge management and safety bodies”. The interests from the organizations was already clearly stated in the Draft D4.2 and more concrete plans for implementation is expected to be addressed during the preparation of the Co-funded European Partnership on Nuclear Materials. The revisions in D4.9 from the “Draft D4.2” are therefore minor.

1. Introduction

The goal of this deliverable is to identify possible protocols of interaction of a Co-funded European Partnership (CEP) on nuclear materials and with organisations, networks and associations addressing development of Codes & Standards, and harmonisation of test and assessment procedures for materials and components relevant to nuclear reactors. The objective is to identify topics and ways of collaboration that would mutually benefit them and a future European CEP on nuclear materials.

Now the whole work has been undertaken in five steps:

1. Define different categories of organisations and then make a list of specific organisations;
2. Based on this list, prioritise the organisations and contact those with the best prospects;
3. Explain the concept of a CEP; identify needs and expectations from the contacted organisations; and confirm support for a CEP on nuclear materials.
4. Write a draft protocol based on the feedback from the contacted organizations (Deliverable 4.2 “*Draft protocol of EJP collaboration with standardisation, data and knowledge management and safety bodies”)*
5. Revision of the Draft protocol (this Deliverable)

Step 1: categories and associated organisations were identified:

- Nuclear design code developers: AFCEN and ASME;
- Standardisation: CEN, ASTM and ISO;
- Regulators and their TSOs: ETSON and WENRA,
- International Organizations: IAEA, GIF;
- Nuclear industry: CORDEL (WNA);
- Pre-normative research: ECCC, EPERC, EMMC, EMCC and ESIS.

Steps 2 and 3: out of these, the following six were singled out (Step 2) for closer discussions (Step 3), as follows:

- AFCEN has a French origin but it is now an international association. It produces nuclear design codes offering accurate and practical rules for the design, construction and in-service inspection of components for use in industrial or experimental nuclear facilities (the RCC- and RSE- codes).

- ECCC was formed in 1991 to co-ordinate Europe-wide development of material data for high temperature applications, in particular creep, with focus on power generation. ECCC is independently governed but with close links to the European industry, through Joint Industrial Projects, which allow the main R&D activities of interest for the group.

- EPERC is a not-for-profit organisation that co-ordinates, develops and promotes the common technical interests and strategies of European scale through pre-normative research and standardisation work.
- CORDEL is part of WNA. It focuses on promoting the international standardisation of nuclear reactor designs and the harmonisation of regulatory requirements, as well as industrial codes and standards, in order to decrease the efforts and modifications needed for a reactor designs deployed in several countries.
- ETSON is the network of 12 national TSOs in Europe. It contributes to the harmonisation of nuclear safety practices within Europe and beyond and carries out joint research programmes on nuclear safety.
- EMMC coordinates activities for different stakeholders including modellers, materials data scientists, software owners, translators and manufacturers in Europe with an overall objective to support the integration of materials modelling and digitalisation critical for more agile and sustainable product development.

ASME was not contacted, as it is primarily a US organisation. The standardisation organisations CEN, ASTM and ISO were not contacted as there is no mechanism for collaboration with a CEP. Nevertheless, involvement of future CEP on nuclear materials in standardisation groups is crucial. It should also be noted that the experts of some networks, such as EPERC, are very active in developing standards, e.g. EN 13445 (Unfired Pressure Vessels).

Regulators need to be independent of industry and are notoriously difficult to include in networks and projects with different stakeholders. Although WENRA was not directly contacted, ETSON is closely linked to the regulators.

The International organisations GIF and IAEA are covered by Deliverable 4.1, and were therefore not approached.

ESIS addresses structural integrity in general and could be an interesting partner in the future, but was not contacted at this stage. The European Materials Characterization Council (EMCC) also looks at the role of integrating digitalisation into the innovation chain but with a focus on material characterisation (including material testing) rather than material modelling. Although it is equally relevant for a CEP on nuclear materials, no discussions were held at this stage.

2. Draft protocols of interaction

AFCEN

In the nuclear energy sector, codes for plant design and construction are a necessary complement to contracts between the operators; buyers of the equipment; and suppliers. Such codes integrate the lessons learnt from prior builds, as well as those from ongoing or planned builds. Design codes are living documents that need to take into account new requirements, as well as integrating new scientific and technical developments. The codes include material data, design rules, acceptance criteria and manufacturing instructions for material and components. The design codes rely heavily on international standards and guidelines. For safety-relevant components, only qualified materials can be included in the design code.

AFCEN (https://www.afcen.com/) was founded 40 years ago to support the design of the French PWRs and SFRs. AFCEN is now an international organisation and the types of reactor and the number of dedicated AFCEN codes have expanded. The codes are regularly updated to meet new requirements and incorporate feedback experience and technical developments. There are five codes related to materials and components, as follows:

- RCC-M: Design and Construction Rules for Mechanical Components of PWR Nuclear Islands;
- RCC-MRx: Design and Construction Rules for mechanical components of nuclear installations: high-temperature, research and fusion reactors;
- RCC-CW: Rules for design and construction of PWR nuclear civil works;
- RCC-C: Design and Construction rules for Fuel Assemblies of PWR Nuclear Power Plants;
- RCC-E: Design and construction rules for electrical and I&C systems and equipment.

Each code has its own sub-committee constituted by the end users. RCC-M and RCC-MRx have traditionally had the closest links to the material research community and can be expected to benefit from a CEP on nuclear materials. In addition to the specific materials, components and operational conditions, there are also other important differences between the needs of the different codes. For instance RCC-M is developed on the basis of the vast operational return of experience from PWRs, which can also be used for long-term operation, whereas for RCC-MRx, which addresses innovative designs with very limited or no operational experience, there is more focus on pre-normative research to demonstrate compliance with the requirements. RCC-MRx is also the selected design code for all European Generation IV reactors.

The AFCEN management expressed a strong interest for the support of, and direct collaboration with, a CEP on nuclear materials. There has always been a close cooperation between AFCEN and the research community, but the link has increased significantly in the last decade and also broadened to a wider international context. There are several reasons for this: new safety requirements, the need for more European harmonization, new reactor types with associated challenges (e.g. different coolants) and not the least the high costs, the need for supporting infrastructures, or simply the need to pool the scientific and engineering expertise.

Recent EURATOM projects that to a large extent were based on the evolution of RCC-MRx or RCC-M include:

- MATTER (2011-2015). This project focussed on ferritic-martensitic steel P91 data to be extended in RCC-MRx: microstructural testing, negligible creep, creep-fatigue, weld factors fatigue; thermal ageing, environmental effect lead and eutectic lead-bismuth for fracture, tensile and corrosion;
- MATISSE (2013–2017). Creep-fatigue P91 and environmental factors (lead, lead-bismuth) P91 and 316L;
- GEMMA (2017-2021). 316L(N) welded joints, special emphasis on environmental effect as basis for design rules in RCC-MRx;
- INCEFA-PLUS (2015–2019). Development of new guidelines for the assessment of environmental fatigue damage susceptibility for NPP components.

Ongoing EURATOM Projects

- NUCOBAM (Nuclear Components based on Additive Manufacturing, started in 2020). The development of a methodology to qualify components produced via additive manufacturing that comply with nuclear codes & standards.
- INCEFA-SCALE (INcreasing Safety in NPPs by Covering gaps in Environmental Fatigue Assessment – focusing on gaps between laboratory data and component SCALE, started in 2020). Environmentally-assisted fatigue of stainless steels (316L) in PWRs under complex waveforms. An assessment of the test results against fatigue curves in nuclear C&S (ASME, RCC-M) is planned in the project
- INNUMAT (Innovative Structural Materials for Fission and Fusion, beginning 2022). The project aims to develop innovative structural materials for nuclear applications and put them on track towards qualification for fission lead-cooled

and molten salt fast reactors as well as fusion DEMO. Materials included are High entropy alloys (HEAs), a new class of materials with a vast development potential and very promising properties, as well as alumina forming austenitic (AFA) steels, already identified as prospective structural materials for Gen IV and Small Modular Reactors, in particular weld overlay and coated 15-15Ti for lead-cooled fast reactors.

- HARMONISE (Towards harmonisation in licensing of future nuclear power technologies in Europe, started in 2022). The objective is to accomplish harmonisation and standardisation of methodologies, codes and standards, as well as the assessment of nuclear reactor components. In the present context WP4 is particular: codes and standards needs of innovative nuclear power plants, where the role of digital technologies and probabilistic framework is of particular interest.

The CEN Workshop 064[1] is also an important platform for collaboration between AFCEN and other nuclear materials stakeholders (reactor designers, R&D organisations and regulators). The current Phase-3 ends in 2022 and a new Phase 4 is in preparation. CEN WS064 is organised in four groups according to RCC-M, RCC-MRx, RCC-CW and RCC-C, respectively. The two main outputs are AFCEN code evolution proposals and R&D proposals in the circumstance that code evolution needs additional pre-normative research. Examples of R&D proposals include: prevention of intergranular corrosion and code basis for additive manufacturing (RCC-M); 60-years design life and compatibility with lead coolant (RCC-MRx); and design to support ageing management and aircraft crash (RCC-CW).

There is an obvious mutual benefit to establish a close collaboration between a CEP and AFCEN. The designer needs and priorities, defined by AFCEN, provide a roadmap for pre-normative research conducted by the CEP research and industrial partners. A wider participation in the of the CEP member organizations in the CEN WS064 is a natural basis to formulate code evolution needs to proposing supporting research programmes. A very wide range of topics with short and long-term perspectives can be foreseen, such as: dedicated test programme for specific materials, revision of specific design rules to more comprehensive changes such as digitalization to support material qualification.

For the revised protocol, AFCEN reiterated again their interests in the future CEP. They envisage to take an active role, for instance as member of the Scientific Advisory Board and/or the Innovation Group. Their focus would

[1] See for instance the CEN WS064 Agreement for Phase 3 *CW17377 Design and Construction Codes for Gen II to IV nuclear facilities (pilot case for process for evolution of AFCEN codes), February 2017*

be evolution and development of nuclear design codes with a broad perspective.

ECCC

ECCC (https://www.eccc-creep.com/) was formed in 1991 to co-ordinate Europe-wide development of creep data for high temperature applications, in particular for power generation. ECCC has a very strong link to industrial applications and is presently organised into four work packages with three material specific Working Groups: WG3A: ferritic steels, WG3B: austenitic steels and WG3C: nickel-based alloys. The work plan is defined by the Joint Industrial Programme (JIP), which is updated every three years. Two main outputs are ECCC data sheets and ECCC Recommendation Volumes. The ECCC activities are almost completely undertaken by in-kind contributions.

The data sheets are provided for selected materials, where the data sets are analysed by validation and data assessment procedures defined by specified ECCC guidelines. Data sheets exist for more than 60 alloys operating in the creep range, including virtually all ferritic and austenitic steels and nickel-based alloys included in the AFCEN codes.

The ECCC Recommendation Volumes consists of nine volumes with recommendations for the generation and assessment of creep data for different applications, including residual life assessments, multi-axial creep, crack initiation and weldments. These recommendations are directly referred to in the RCC-MRx code.

The nuclear sector had initially a high profile in ECCC, but this subsequently declined. With this trend apparently now reversing, there is one ongoing project related to long-term creep properties for 316L(N) welded plates and a new project on demand from the fusion community will start on data sheets for EUROFER ferritic-martensitic steel for inclusion in RCC-MRx. The present JIP 2022–2024 has indicated a number of topics with high nuclear relevance to be investigated: creep-fatigue data and evaluation procedures, 60 years design life, micro-mechanical testing and transferability to standard tests, evaluation of weld strength reduction factors.

One important factor is that ECCC interacts closely with CEN and ISO Technical Committees.

The executive committee of ECCC has expressed a strong interest for collaboration with a future CEP on nuclear materials. ECCC provides a link to industrial partners, non-nuclear power generation stakeholders and standardisation bodies. ECCC is in principle open for any topic related to high-temperature creep testing and data assessment. One specific ECCC contribution could be data assessment and establishment of data sheets for new materials where ECCC could provide access to additional data and methods.

The interest to support a CEP on nuclear materials and also direct involvement in joint projects was also reiterated for the revised protocol. This could be addressed in a bi-lateral agreement covering commonalities between the CEP-NM and the ECCC-JIP. Since there is a strong UK contribution to ECCC, any agreement between EURATOM and the UK would improve the possibilities for collaboration. The German engagement to ECCC is also traditionally very strong, which could also be an advantage.

EPERC

EPERC (https://www.eperc-aisbl.eu/) co-ordinates, develops and promotes the common technical interests and strategies of European industry with regard to pressure equipment through:

a) research in relation to the international context and European institutions,

b) disseminate research results and industry experience and facilitate the transfer of technology into practice;

c) exchange of industry experience in the design, fabrication, inspection, monitoring and safe life assessment and,

d) improving the codes and standards by providing industry and research information and data.

EPERC publishes technical documents with guidelines and recommendations for design, testing, operation, inspection and maintenance of pressure vessels. Typical activities include: comparison of International Codes & Standards; identification of gaps & needs with Code Organization and Industry; performance of benchmarks on practical cases; development of recommended Practices with all the rules validation.

EPERC assists and advises authorities involved with legislation, standards and other issues concerning pressure equipment at a European level. EPERC is a member of the Working Group Pressure Equipment of the DG GROW of the European Commission.

EPERC also has very close links with CEN Technical Committees and is promotor of the family of EN 13445 standard for the design and assessment of unfired pressure vessels in support of the Pressure Equipment Directive PED 2014/68/EU.

EPERC organizes conferences, seminars and workshops in the field of pressure equipment and pressure plant, with the collaboration of relevant stakeholders worldwide, including CEN and third country organizations such as ASME, JSME.

EPERC expressed great interest in collaboration with a CEP on nuclear materials. Special emphasis would be expected for review and update of the codes, e.g. in relation to EN 13445, based on pre-normative research. A prior example of a relevant collaboration is the recent revision of EN 13445 with a new method to determine the negligible and no-creep temperatures for steels conducted that involved EPERC and members of ECCC and EERA JPNM.

EPERC confirmed their interest to support a future CRP on Nuclear Materials. They highlighted again that they see their main role to disseminate research results and industry experience for pressure vessel equipment.

CORDEL

In 2007 the WNA established the Cooperation in Reactor Design Evaluation and Licensing (CORDEL) Working Group, with the aim of stimulating a dialogue between the nuclear industry and nuclear regulators on the benefits and means of achieving a worldwide convergence of reactor safety standards for reactor designs. CORDEL has issued regular status and opinion reports on related areas, such as: Nuclear Standards Harmonization, Standardization of Reactor Designs, and Facilitation of International Licensing of SMRs.

The discussion with CORDEL was quite informal. CORDEL would favour data-centric activities using digital technologies, covering material data under various operating conditions. To overcome the challenge of sparse data for nuclear materials a combination of probabilistic methods an Artificial Intelligence should be explored. A strict contractual collaboration between CORDEL and a European CEP on Nuclear Materials is probably more complicated, since CORDEL is a worldwide organisation directly linked to the nuclear industry. Nevertheless, the overall objectives to achieve improved safety, reduced cost and quicker deployment of nuclear energy through closer integration and harmonisation are shared. Thus, CORDEL, or at least its wider interests, may be represented indirectly by the European industrial partners.

For the revised protocol, Nawal Prinja, as representative for CORDEL, expressed a clear interest for direct involvement in the future CEP. Joining the Scientific Advisory and/or alternatively the Innovation was proposed.

The collaboration with CORDEL would be simplified if there were an agreement between the EU and the UK.

ETSON

ETSON (https://etson.eu/) provides a common platform to its 13 national member organisations. Their main task is to provide competent, reliable and impartial technical expertise to the nuclear regulatory body of their respective country, in particular with respect to scientific support. A major output is the Technical Safety Assessment Guides. ETSON actively promotes cooperation and information exchange between its members, but also has a wider EU perspective.

Most of the ETSON members are also SNETP members and four are also members of EERA JPNM. Collaboration between the promoters of the CEP and the national ETSON organisations is already in place. It should be kept in mind, though, that ETSON focusses on nuclear safety and since ETSON is closely linked to the regulators some restriction may apply for collaboration within a CEP on nuclear materials, in particular in case there is strong involvement of industrial partners and potential conflict of interest. This aside, there are a large number of areas where nuclear safety is the primary challenge and where mutual benefit for ETSON and a CEP can be identified.

The support from ETSON was re-confirmed for the revised protocol, but also that contribution would primarily come through the national members.

EMMC

EMMC (https://emmc.eu/) is a legal entity founded in 2019. Its main objective is to promote and enhance the integration of materials modelling and digitalisation with special emphasis on the deployment of such methods by European industry[2].

The development of new or improved materials as well as prediction of material degradation and life assessment in the last decade has been quite remarkable. This paradigm shift has to a large extent been driven by integrating advances in digitalisation and big data with material modelling and simulation. In this context, the EMMC has identified five interlinked focus areas, as follows:

[2] See The EMMC Roadmap for Materials Modelling and Digitalisation of the Materials Sciences, October 2020, https://zenodo.org/record/4272033#.Y01x8LZByCp

1. Model development including development and integration of physics-based and data-driven models from atomistic to continuum scale. Much focus should be on verification (testing of computer model) and validation (testing against physical data) of the models;
2. Digitalisation and interoperability, which includes all aspects of representing, accessing and using digital data. Interoperability refers to the ability to exchange information between common systems to perform complex tasks that cannot be done by the single systems. Standardised data documentation based on the FAIR principles and promotion of Open Access platforms are important aspects. The development of a common European Materials and Modelling Ontology is central for integration of codes and systems interoperability as well as standards for materials modelling terminology and classification[3];
3. Deployment of high quality software tools for e.g. models and interoperability linking different part for wider European use.
4. The industrial deployment of the developed material modelling system for the design and manufacturing of new materials and their qualification is the core objective of EMMC. This requires holistic strategies including people, processes, models and data adapted to the industrial needs.
5. The final focus area is to actively communicate the importance of materials modelling and digitalization to support the competiveness of the European industry and promote activities at European level.

In addition to roadmaps, EMMC also produces reports and White Papers on related topics. EMMC also provides a platform for projects in related areas.

The key challenge for nuclear materials is the very lengthy time for qualification of new materials and qualification of existing material for new requirements. This is due to the very harsh conditions that nuclear components are exposed to in combination with very strict regulations. Consequently, the optimal solutions in terms of cost and performance are not adopted. Modelling supported by digitalisation is believed to become a key factor to reduce the time and cost for material and component qualification, by reducing the need for testing, in particular if it is being integrated already at the design stage. Since the nuclear one is among the sectors that could potentially benefit most from this paradigm shift, it could also be a main promotor for development and deployment of modelling and digitalisation. Thus, there is a mutual benefit for a closer collaboration between a European CEP on nuclear materials and EMMC.

[3] CWA 17284 Materials modelling - Terminology, classification and metadata, April 2018 and CWA 17815 Materials characterisation - Terminology, metadata and classification, October 2021.

EMMC representatives expressed strong interest for collaboration with a CEP on nuclear materials. EMMC provides a range of ways in which collaborations can be supported and facilitated. These include interactions with EMMC AISBL as an association, or between organisations that can be members of EMMC, as well as individual members. EMMC recognises 'EMMC related initiatives' which are represented by an EMMC Organisational Member and EMMC provides dissemination opportunities for those. EMMC members can also lead and take part in Task Groups, so for example one could envisage a Task Group on nuclear materials models and digitalisation that brings together stakeholders interested in this topic. Typically, these Task Groups are supported by various projects and can indeed lead to new projects and collaborations.

The support from EMMC is ensured again, but more detailed discussions on concrete actions and implementation are foreseen to be discussed as part of the preparation of the CEP on Nuclear Materials.

3. Concluding Remarks

It is very important for a future CEP on nuclear materials to establish close contact and collaboration with organizations addressing codes, standards, data and knowledge management. This requires that there be a mutual benefit for the CEP and the targeted organizations. The objective of this Deliverable was to identify key organizations, explain the objectives and the concept of a CEP on nuclear materials and then to explore to what extent there is an interest and in that case what form a future collaboration could take. To this end, six organizations were contacted: AFCEN, ETSON, ECCC, EPERC, CORDEL and EMMC. Positive feedback was received from each organization, but the level and form of collaboration will differ.

- There is already established close interaction between AFCEN and the nuclear materials community. The establishment of a CEP is expected to further strengthen this collaboration. AFCEN confirmed their commitment to support a CEP on Nuclear Materials.
- Most of the ETSON members already have some collaboration with SNETP and EERA JPNM, or are already member of these, so future integration with a CEP is expected, but not necessarily under the ETSON umbrella, since the close links with the national regulators may impose some restrictions.
- ECCC and EPERC work closely with power industry and there is significant overlap with the objectives of a CEP on nuclear materials. There is clearly mutual interest for further collaboration. Their support to a CEP on Nuclear materials was confirmed.

- CORDEL representing nuclear industry globally would be a very important partner. Formal collaboration may be more difficult to establish, but should be further explored. Nawal Prinja, who is the CORDEL vice-chair and chairman of its Mechanical Codes and Standards Task Force, expressed his direct interest to join the Scientific Advisory Committee.
- A closer integration between a CEP and ECMM has very high potential as the increased use modelling and digitalization is expected to be the key factor for reducing time and cost for material qualification, which today is a key challenge for the nuclear sector. This should be further elaborated upon in the preparation of the CEP-NM.
- There are a large number of activities in the UK and UK organizations are also key partners of in particular EPERC, ECCC, CORDEL and ECMM. An agreement between EURATOM and the UK would be very beneficial for involvement of these organizations in a future CEP on Nuclear Materials.

The Draft Protocol (Deliverable 4.2) outlined the interests and potential contribution from the contacted organizations. Their interest and support expressed in the Draft Protocol was also confirmed in the revised protocol. The Draft protocols included already specific contributions so the revision in this document is rather minor. The EURATOM Work Programme 2023-2025 was published in March 2023 including the preparation of the CEP: “HORIZON-EURATOM-2023-NRT-01-04: Co-funded European partnership for research in nuclear materials”. More detailed discussion on the collaboration should take place during the preparation of the proposal to answer the call.

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